National Aeronautics and
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RESEARCH ANNOUNCEMENT

SAGE III OZONE LOSS AND VALIDATION EXPERIMENT (SOLVE)

Proposals Due August 31, 1998

OMB Approval No. 2700-0087

SAGE III OZONE LOSS AND VALIDATION EXPERIMENT (SOLVE)

NASA Research Announcement
Soliciting Research Proposals
for
Period Ending
August 31, 1998

NRA 98-OES-08
Issued June 30, 1998

Office of Earth Science
National Aeronautics and Space Administration
Washington, DC 20546

Research Announcement for the

SAGE III Ozone Loss and Validation Experiment (SOLVE)

A NASA DC-8, ER-2, and High-Altitude Balloon Mission

The proposed **S**AGE III **O**zone **L**oss and **V**alidation **E**xperiment (SOLVE) is a measurement campaign designed to examine the processes controlling ozone levels at mid- to high latitudes. Measurements will be made in the Arctic high-latitude region in winter using the NASA DC-8 and ER-2 aircraft, as well as balloon platforms. The mission will also acquire correlative data needed to validate the Stratospheric Aerosol and Gas Experiment (SAGE) III satellite measurements that will be used to quantitatively assess high-latitude ozone loss. SOLVE is co-sponsored by the Upper Atmosphere Research Program (UARP), Atmospheric Effects of Aviation Project (AEAP), Atmospheric Chemistry Modeling and Analysis Program (ACMAP), and Earth Observing System (EOS) of NASA's Earth Science Enterprise (ESE) as part of the validation program for the SAGE III instrument.

The SOLVE mission builds on the polar studies of the two highly successful Airborne Arctic Stratospheric Expeditions (AASE and AASE II) that took place in the winters of 1988-1989 and 1991-1992, respectively. Objectives for those two missions included evaluating the potential of Antarctic-like ozone losses occurring in the Arctic. These past missions, satellite observations, and various international measurement campaigns have increased our understanding of polar processes and have refined our questions. Since AASE and AASE II, new instrumentation has been developed for answering questions that could not be addressed previously. These new instruments, our improved understanding, and our experience during the AASE missions have led to the development of the scientific strategy for SOLVE.

The SOLVE mission science/validation goals are described in more detail in Section 1 of Appendix A, while the implementation plan is outlined in Section 2 of Appendix A. These goals establish the measurement/instrument requirements. The mission will occur over the October 1999 to March 2000 period. The NASA DC-8 and ER-2 aircraft will carry instruments to examine Arctic ozone loss, halogen activation by aerosols and cirrus clouds, and properties of polar stratospheric clouds, and to aid SAGE III validation. High-altitude balloons will carry both *in situ* and remote-sensing instruments to examine the origin and composition of air that comprises the Arctic polar vortex, to study halogen activation and reactive nitrogen removal by cold aqueous particles, and to aid SAGE III validation. Intercomparison of the measurements made by these complementary aircraft- and balloon-borne instruments will enhance the scientific return and provide an increased understanding of the atmospheric radiative, dynamical, and chemical framework within which chemical ozone loss can be evaluated. They will also help to improve confidence in assessments of the atmospheric effects of future high speed civil transports (HSCTs)

We expect to select instrument participants and a small theory team in late-summer 1998. Individual instrument upload and testing on the ER-2 aircraft will occur during the summer and fall of 1999, while the complete payload integration and tests will likely occur in January 2000. Instrument upload and testing on the DC-8 aircraft will begin in mid-October/early November 1999. The ER-2 will most likely be based at a high-latitude site such as Stavanger, Norway. The DC-8 will also be based at a high-latitude site such as Fairbanks, Alaska; Keflavik, Iceland; or Stavanger, Norway. The balloon launches will possibly occur from Sondestrom, Greenland; Thule, Greenland; Kiruna, Sweden; or Andoya, Norway. Theory teams are expected to participate in field deployments. These teams will be utilized in mission and flight planning, in the analysis of observations, and in other phases of the SOLVE mission. Instrument and meteorological data will be made available to all investigators within approximately 24 hours after each flight. Mission activities will be broadcast in near-real time via e-mail and a WWW site. Such rapid data turnaround enhances analysis and feeds back into flight planning.

Proposals should focus on the FY00 performance period, which is the period when the balloon and aircraft deployments will occur. Requests for support in FY99 for pre-mission activities and in FY01 for post-mission analysis will be considered, however it is expected that resource requirements in FY99 and FY01 will be significantly less than those needed in FY00. Proposals may be submitted at any time during the period ending August 31, 1998, but no later that 4:30 p.m. (EDT) on August 31, 1998. Proposals received after that date will be handled in accordance with the NASA policy concerning late proposals (NFS 1815.412). Proposals will be panel reviewed by approximately September 30, 1998. If accepted, they will be integrated into the FY99 research program.

Participation in SOLVE is open to all categories of organizations: educational institutions, industry, non-profit institutions, NASA centers, other US Government agencies, and international educational institutions, industries, and government agencies.

Funds are not presently available for awards under this NRA. The Government's obligation to make awards is contingent upon the availability of appropriated funds from which payment for award purposes can be made and the receipt of proposals which the Government determines are acceptable for award under this NRA.

Appendix A contains the scientific objectives and the technical description of the SAGE III Ozone Loss and Validation Experiment (SOLVE). Appendix B contains the basic guidance needed for preparation of proposals in response to an NRA. Appendix C provides guidance for foreign participation. Appendix D includes required certifications and proposal cover sheet, which must be completed and returned to NASA with any proposal submitted in response to this NRA.

Identifier: NRA-98-OES-08

Submit Proposals to:

SOLVE NRA
Code Y
400 Virginia Avenue SW, Suite 700
Washington, DC 20024

For overnight mail delivery purposes only the recipient telephone number is (202) 554-2775.

Copies Required:	10
Selecting Official:	Director, Research Division
Obtain Additional Information From:	Dr. Michael J. Kurylo, Manager Upper Atmosphere Research Program NASA Headquarters, Code YS Washington, DC 20546 Tel.: (202) 358-0237 Fax: (202) 358-2770 e-mail: mkurylo@hq.nasa.gov

Your interest and cooperation in participating in this opportunity are appreciated.

Ghassem Asrar
Associate Administrator
Office of Earth Science

Enclosures:

Appendix A, "Technical Description of the SAGE III Ozone Loss and Validation Experiment (SOLVE)"

Appendix B, "Instructions for Responding to NASA Research Announcements"

Appendix C, "Required Certifications and Cover Sheet"

Appendix D, "Guidelines for Budget Preparation"

Appendix E, "Guidlines for Foreign Proposals"

APPENDIX A:

Technical Description of the SAGE III Ozone Loss and Validation Experiment (SOLVE): A NASA DC-8, ER-2, and High-Altitude Balloon Mission

1 SCIENCE OBJECTIVES

What are the processes and variables that control ozone concentrations over the course of the winter (e.g., temperature, water, HNO_3, halogens, aerosols, etc.)?

The primary science objective of SOLVE is to further understand the processes that control polar stratospheric ozone levels. This objective is driven by recently observed Arctic ozone losses that have reached levels that are becoming comparable to Antarctic losses. Figure 1 displays images of March total ozone over the Arctic for a series of 8 years. In comparison to the early years (1971, 1972, 1979, 1980), the last few years have shown a region of low ozone centered on the polar region. Where we typically saw an ozone high over the polar cap, polar ozone averages in the 1990s have decreased below 400 Dobson Units (DU) with a value of 355 DU in 1997 [Newman *et al.*, 1997]. Ozone values recovered during March 1998 to a more normal value of about 430 DU, illustrating the effects of higher temperatures and the interannual variability of the polar stratosphere.

The large Arctic ozone losses observed over the last decade cannot be explained adequately by current atmospheric models. This inability to quantitatively explain ozone losses undercuts our ability to predict future ozone changes. These future changes will result from: 1) changes in halogen loading of the stratosphere; 2) changes in H_2O, NO_y, and aerosols from aircraft effluents or volcanic events, CH_4 and N_2O; 3) temperature changes; and 4) changes in the atmosphere due to increases of greenhouse gases.

1.1 Observed Changes in High-Latitude Winter Ozone

The observed ozone losses in the polar region are a direct result of the conversion of inorganic chlorine from reservoir species (HCl and $ClONO_2$) to free radical form as in the Antarctic [see Brune *et al.*, 1990; Toohey *et al.*, 1993]. This conversion occurs via heterogeneous reactions on the surfaces of stratospheric particles and aerosols. Although polar stratospheric clouds (PSCs) were initially believed to be responsible for inorganic chlorine processing, experiments have shown that the conversion of HCl and $ClONO_2$ also occurs on cold nitrate/sulfate/water ternary solutions. Figure 2 displays reactivities of these chemical reactions as a function of temperature and particle type, illustrating that the reactivity is highly temperature dependent. Hence, the overall science objective will focus on the free radical chemistry that causes ozone loss and those microphysical processes that control the partitioning of the halogen and nitrogen species.

The temperature of the stratosphere controls the timing of the conversion of inorganic chlorine to reactive forms. Cold winters (less than 195 K) with late polar vortex breakups (April) are associated with very low ozone levels (e.g., 1997), while warmer winters with early breakups are associated with high ozone levels (e.g., 1989). Consequently, the details of the evolution of the winter temperatures and the mesoscale to planetary scale waves that control these temperatures are key issues for understanding polar chemistry.

1.1.1 The origin and composition of air comprising the Arctic polar vortex in early winter

Understanding and measuring the initial state of air comprising the Arctic stratosphere is important for interpreting the subsequent low temperature chemistry and ozone loss. It is critical to measure the initial states for ozone, the nitrogen (NO_y) and halogen (Cl_y) compounds, because these constituents will interact with aerosols, and the HNO_3 and H_2O vapors that condense to form PSCs. Finally, remote observations can define initial profiles of total reactive chlorine (Cl_y) and nitrogen (NO_y), as well as H_2O, CH_4, HNO_3, HCl, $ClONO_2$, and ozone within the vortex. During SOLVE, measurements of these initial profiles will precede detailed process studies conducted by the ER-2 and DC-8.

Observations of the initial state of the Arctic stratosphere will allow for better understanding of the role of transport on the evolution of Arctic ozone during a typical winter. They also permit more reliable model predictions of the sensitivity of vortex composition to exhaust from (current and future) subsonic and (future) supersonic aircraft.

1.1.2 Polar ozone loss during midwinter

Results from the 1995 DC-8 Tropical Ozone Transport Experiment and Vortex Ozone Transport Experiment (TOTE/VOTE; information available on the World Wide Web at http://hyperion.gsfc.nasa.gov/Analysis/aircraft/tote/vote_top.html), along with modeling studies, suggest that models cannot currently account for the amount of ozone lost during the winter [Hansen *et al.*, 1997; A. Douglass, private communication]. This discrepancy has also been reported in comparisons with data taken during recent European campaigns [Hansen *et al.*, 1997; Bregman *et al.*, 1997]. The TOTE/VOTE measurements suggested that mixing is taking place in the polar lower stratosphere (25 to 14 km). However, calculations suggest that these mixing estimates can have significant errors [Sobel *et al.*, 1997]. Mid-latitude air mixes into the vortex and replaces the air that contains more ozone, which is descending out of the vortex base as a result of diabatic cooling. It is apparent that we still have a poor understanding of the balance of ozone production, loss and transport in the lower stratosphere even in the early-winter period when chlorine chemistry is not very active.

Figure 3 illustrates the origin of air at ER-2 flight altitudes in early March. The data points are diabatic trajectory positions on the 500 K isentropic surface (~21 km), which were initialized on 1 March 1995 over an equal area grid within the vortex (regular grid of faint dots on top right image inside the polar vortex, blue dots on bottom panel). The air parcels (run backward in time for 150 days to 1 October 1994) originated at about 650 K (27 km, white dots on bottom panel) mainly from the mid-latitude regions (black dots on top left false color image of potential vorticity). During SOLVE, meridional mixing will be estimated from models such as these trajectory models. As was done during TOTE/VOTE, the validity of these models will be tested against the ozone profiles.

1.1.3 Uncertainties associated with conventional techniques for calculating chemically driven ozone losses

Various techniques are employed to measure ozone losses in the northern polar region. Newman *et al.* [1997] used Total Ozone Mapping Spectrometer (TOMS) data to calculate an ozone trend and showed that levels in the 1990s were about 100 DU lower than levels observed in the 1970s. Müller *et al.* [1997] used observations made by the Halogen Occultation Experiment (HALOE) to estimate a 70- to 80-DU loss of ozone during March 1997 using methane as a conservative tracer of atmospheric motion. Von der Gathen *et al.* [1995] has combined ozonesondes and trajectories to estimate a 38% loss of ozone at the 475 K isentropic surface during the January to February 1992 period. Rex *et al.* [1997] used the same technique to calculate a 64% loss from 20 January 1995 to 9 April 1996.

During SOLVE we will attempt to validate and assess uncertainties associated with the techniques that have been used to measure ozone loss. We will try to quantitatively determine relative contributions to low ozone levels from interannual variations in ozone transport, and ozone photochemistry. As halogen levels decrease in the stratosphere in response to international regulations, a clear understanding of the uncertainties associated with the loss measurements is necessary to determine statistical significance.

Profiles of ozone, hydrogen fluoride (HF), and CH_4 in the incipient vortex greatly aid the estimation of ozone loss rates from measurements by the HALOE instrument on NASA's Upper Atmosphere Research Satellite (UARS), which typically does not sample the vortex until later in the season. The loss calculations of Müller *et al.* [1997] using the relatively sparse HALOE ozone, HF, and CH_4 data must be carefully understood within respect to deep vortex samples acquired by aircraft and balloon. Horizontal and vertical gradients of these gases should be carefully compared to the observations of HALOE to determine the representativeness of these profiles. Further, high quality *in situ* observations of these tracers enables an aircraft analysis of losses that can be directly compared to HALOE loss calculations over the course of the ER-2 flight series.

1.2 Processes that Extract and Insert Nitrogen and Chlorine Compounds into Reservoir Species and the Distinction between Liquid and Solid Phases

The critical period for ozone loss occurs as the sun begins to return to the Arctic region during the January to April period. As air inside the polar vortex cools during November and December, particles will form. Heterogeneous reactions occur as this air passes through the low temperature regions (i.e., the air is processed by heterogeneous reactions). This initial processing typically occurs in December. Temperatures typically rise above the nitric acid trihydrate saturation temperature in February. Figure 4 displays a timeline of the areal coverage of polar lower stratospheric temperatures. Each year's area (the winter of 1978-79 is denoted by 79 on the abscissa) is indicated by the width of the vertical lines on the plot for temperatures less than 200, 195, and 190 K. For example, on 1 April 1997 (near the top right of the figure) the area contained by the 200 K isotherm is 2.2 million km^2. However, as mentioned earlier, because air can still be processed on cold sulfate aerosols, processing becomes insignificant only when temperatures rise above about 205 K in spring. Reaction probabilities on cold sulfate aerosols increase by nearly four orders of magnitude as the temperature decreases from 205 to 190 K (see Figure 2). Hence, the February to March period is critical for understanding ozone loss because most of the inorganic chlorine has been activated into reactive form by these particles and the sun has steadily risen over the Arctic, providing the energy flux necessary for fueling these ozone loss catalytic reactions.

Denitrification in the Arctic is much less than over Antarctica. Winter Arctic temperatures are much higher than Antarctic. Consequently, the number of large particles that can settle out of the stratosphere is substantially less. Further, the Arctic polar vortex is warmer and weaker in late winter, usually breaking up significantly earlier than the Antarctic polar vortex (see http://hyperion.gsfc.nasa.gov/Data_services/met/nmc_climatology.html). Temperatures low enough to form ice particles (~188 K) are infrequent in the Northern Hemisphere, as is indicated by the relative lack of blue coloring on Figure 4 (T < 190 K). While Antarctic lower stratospheric temperatures usually drop well below the frost point in midwinter, the Arctic vortex has only a few days in which temperatures fall below the frost point (at least on synoptic scales). Sampling of such extremely cold events will add a key piece of evidence to our understanding of denitrification.

The degree of ozone loss is extremely sensitive to the timing of the disappearance of cold temperatures and polar vortex breakup. Figure 4 shows that temperatures fall below 200 K beginning in mid-November and have typically risen above 200 K in about mid-March, with the 1996 and 1997 temperatures rising above 200 K in early April. Sampling of air that is in the 195- to 205-K temperature range should yield evidence of processing by cold aerosols during the late-winter breakup period.

Recent work by Carslaw *et al.* [1998a] analyzed the impact of mountain forced gravity waves on the temperatures of the lower stratosphere. Figure 5 [private communication, J. Bacmeister; see also Carslaw *et al.* 1998b] displays backscatter ratios for PSCs observed over northern Scandinavia. Because there are large vertical excursions of air within these waves, there are large temperature excursions as air parcels move through these waves. Such events can have a significant impact on chlorine activation in the polar region because the time scales for activation are short while chlorine deactivation time scales are long; the flow speeds through these mountain wave events are fast, and there are a number of mountain ranges in the Northern Hemisphere which can spawn such waves. The spatial and temporal evolution of such waves are not observable by the conventional synoptic network and satellite measurement techniques.

Observations of such waves by aircraft will significantly improve our understanding of the effects of mesoscale features on the chemistry of the polar vortex and mid-latitudes.

1.2.1 Chlorine activation and denitrification

The activation of chlorine involves a number of science questions. The first series of questions concerns the details of the particles that lead to chlorine activation. Specifically, what is the seasonal evolution of these particles, how does this evolution impact the reaction probabilities over the course of the winter season, and how do the particles evolve from cold aerosols to crystalline forms such as nitric acid trihydrates. The details of these phase transitions may have implications for the denitrification processes and for chlorine activation. The second series of questions involves the detailed chemical evolution of the nitrogen and chlorine budgets over the course of the winter due to repeated activation events. The principal heterogeneous reactions are:

$N_2O_5 + H_2O$ Æ $2\ HNO_3$ (1)
$ClONO_2 + H_2O$ Æ $HOCl + HNO_3$ (2)
$ClONO_2 + HCl$ Æ $Cl_2 + HNO_3$ (3)
$BrONO_2 + H_2O$ Æ $HOBr + HNO_3$ (4)
$HOCl + HCl$ Æ $Cl_2 + H_2O$ (5)
$HOBr + HCl$ Æ $BrCl + H_2O$ (6)

Reactions (2), (3), (5), and (6) repartition the Cl_y towards ClO, while Reactions (1), (2), (3), and (4) shift NO_x into HNO_3, suppressing the NO_2 that will deactivate the ClO. The rates of these multiphase reactions need to be tested under actual atmospheric conditions for assessing our predictive capabilities.

In particular, the impact of mesoscale temperature perturbations that result from mountain waves needs to be considered in addition to the activation events that result from synoptic scale systems. Additional questions involve the details of denitrification processes that extract reactive nitrogen from the lower stratosphere. Dehydration and denitrification may actually reduce ozone loss by reducing the surface area of particles in the lower stratosphere, and thereby reduce activation of reactive chlorine.

Data presented by Avallone *et al.* [1993] showed that ClO in the lower stratosphere was enhanced relative to the concentrations calculated from models that include heterogeneous conversion of N_2O_5 to nitric acid on sulfate aerosol (Reaction (1) in Section 1.2.1). These data were measured during a high aerosol period as a result of the Mt. Pinatubo eruption. Ozone loss rates calculated from these measured ClO values were three times larger than predicted by standard models at 16 km. Contributing to this enhanced ozone loss were reactions from the ClO_x, BrO_x, and HO_x families. Avallone *et al.* [1993] speculated that chlorine nitrate is a much larger fraction of the inorganic chlorine budget than most models predict. Subsequent to the publication of Avallone *et al.* [1993] laboratory measurements have shown that heterogeneous reactions of bromine compounds (e.g., $BrONO_2$, HOBr) are considerably faster than their chlorine counterparts, and it is possible that such reactions can convert some HCl into chlorine nitrate in the lower stratosphere. Because HCl is the dominant reservoir of inorganic chlorine in the lowermost stratosphere and active chlorine is more easily released from $ClONO_2$ than from HCl, even a small conversion of HCl to $ClONO_2$ can result in significant enhancements of ClO.

Recently, Solomon *et al.* [1997] have proposed that inorganic chlorine can also be activated rapidly in cirrus clouds at the lowest stratospheric altitudes, and that resulting increases in ClO could be responsible for significant downward trends in ozone that have been observed by SAGE II. Unfortunately, there have been few direct measurements of ClO in cirrus, and those that exist have been ambiguous [Borrmann *et al.*, 1997]. Solomon *et al.* [1997] predict that heterogeneous reactions of $ClONO_2$ and HCl can result in enhanced ClO mixing ratios as high as 10 parts per trillion (ppt) in summer and 50 ppt or higher in winter in the region near the tropopause (abundances that are readily detectable by existing *in situ* instruments). Such enhanced ClO could have a role in ozone loss in the lowermost stratosphere. Examination of the potential for cirrus activation is important in assessing the impacts of aircraft flying in this atmospheric region.

1.2.2 Chlorine deactivation and ozone loss

Our current understanding of the termination of chlorine catalyzed ozone loss depends on the reintroduction of NO_2 into the gas phase where it reacts with ClO to form the relatively long-lived $ClONO_2$. The NO_2 is formed by the photolysis of nitric acid (HNO_3 + h**n** Æ NO_2 + OH). The processes in the ozone loss cycles are:

	ClO + ClO	Æ	ClOOCl
	ClOOCl + h**n**	Æ	Cl + ClOO
	ClOO + M	Æ	Cl + O_2 + M
x 2	Cl + O_3	Æ	ClO + O_2
Net:	2 O_3	Æ	3 O_2

and

	ClO + BrO	Æ	Cl + Br + O_2
	Cl + O_3	Æ	ClO + O_2
	Br + O_3	Æ	BrO + O_2
Net:	2 O_3	Æ	3 O_2

Key chemistry questions include:

1) Can we demonstrate the deactivation of ClO by NO_2?

2) What is the evolution of the reservoir species ($ClONO_2$ and HCl) following ClO deactivation?

3) Can we show that the formation of ClOOCl is a principal part of the loss mechanism?

4) What are the relative contributions among catalytic loss cycles to the overall ozone loss over the winter to spring period?

The total loss of ozone is determined by the competition between these catalytic reaction chains as temperatures rise during spring. If the low temperatures persist into late March, the chlorine is maintained at high levels and the nitrogen continues to be sequestered in HNO_3. With 1) high reactive chlorine levels, 2) sequestered nitrogen, and 3) solar visible and UV in the northern polar region, ozone loss rates become extremely large. Hence, the details of the ClO deactivation is critical to an accurate calculation of net ozone loss.

1.3 Properties of Cold Aerosols and Polar Stratospheric Clouds

One of the major issues concerning polar stratospheric ozone loss is to understand the composition of PSCs. Reaction rates vary depending upon whether the aerosols are solids or liquids. They also vary with cloud exposure, frequency, and conditions of cloud formation. At present it is thought that many of the clouds are supercooled nitric acid/sulfuric acid/water solutions. However, DC-8 lidar data from AASE indicate that the aerosols were solids more than half the time PSCs were observed [Browell *et al.*, 1990]. Measuring particle phase is essential because the particle composition and phase dictates halogen conversion rates. Such new data will also help to improve the parameterization of heterogeneous processes in assessment models, particularly those focusing on the atmospheric effects of HSCTs which emit H_2O, sulfate, and NO_y in the lower stratosphere.

1.4 SAGE III Validation

SAGE III is the latest in a family of solar occultation satellite instruments designed to monitor distributions of stratospheric and upper tropospheric aerosol, ozone, water vapor, and nitrogen dioxide (see http://arbs8.larc.nasa.gov). Significant technical advancements over its predecessor (SAGE II) will also permit the measurement of temperature and pressure, as well as measurements during lunar occultation events of the nighttime species NO_3 and OClO [McCormick *et al.,* 1996]. The first of three SAGE III instruments is scheduled for launch in March 1999 in a sun-synchronous orbit onboard the Russian Meteor 3M spacecraft. Solar occultation measurements of SAGE III will occur mostly at high latitudes, while lunar occultation events will vary from pole to pole. Figure 6 shows the expected SAGE III measurement locations throughout the year.

Validation of SAGE III science products requires airborne and balloon correlative measurements that are in close temporal and spatial coincidence in order to reduce uncertainties in representative sampling. Added correlative measurements are also needed along the line-of-sight between the satellite and the sun (or moon) to assess the impact of constituent inhomogeneity on the retrieval algorithm. This is especially true in the presence of polar stratospheric clouds or cirrus. The measurement requirements specified below are discussed further in the SAGE III Validation Plan [McCormick *et al.,* 1997].

2 SCIENCE IMPLEMENTATION

This is a preliminary plan for determining platforms, instruments, and basing requirements for attacking the science objectives outlined in Section 1. This plan will evolve as additional capabilities are added to or deselected from the mission. Proposals should give careful consideration to this plan, but the specifics should be understood within the context of a pre-planning stage. An updated implementation plan will be developed following selection of instruments and investigators, and this plan will be further refined following the initial SOLVE science team meeting. Section 3 follows from this section as a summary of this preliminary implementation plan.

2.1 Observed Changes in High-Latitude Winter Ozone

2.1.1 The origin and composition of air comprising the Arctic polar vortex in early winter

Measurements in the polar vortex of ozone, the nitrogen (NO_y) and halogen (Cl_y) compounds are required, because these constituents will interact with aerosols, and the HNO_3 and H_2O vapors that condense to form PSCs. These observations need to be made up to high altitudes at high latitudes. The only measurement/platform capabilities available for high-altitude measurements are balloon-borne, satellite, DC-8 lidar, and ER-2 observations in the lower stratosphere. Polar measurements of long-lived trace gases need to be combined with tropical observations to help quantify how much of the midwinter vortex is composed of stagnant summertime polar air, mid-latitude air on the same isentropic level, and higher altitude air that has descended from above.

High-altitude (balloon-borne) measurements allow this issue to be examined in several ways. First, the simultaneous vertical profiles of long-lived trace gases permit the diagnosis of rates of vertical descent and meridional mixing. Second, the observations of CO_2 and SF_6 yield the average age of the air being sampled. Third, scatter plots of different pairs of long-lived species define distinct relations for polar, mid-latitude, and tropical air masses. Quantifying transport is important for separating ozone changes caused by atmospheric dynamics from those changes driven by chemistry.

2.1.2 Polar ozone loss during midwinter

To attack the issue of ozone chemistry and transport in the lower stratosphere during winter, the SOLVE mission will use *in situ* and remote ozone, temperature, trace gas, aerosol, and water vapor measurements from the NASA ER-2, DC-8, and balloons.

The DC-8 will be flown across the vortex several times during the early and midwinter periods to develop a climatology, which, when combined with the balloon information, can be used to estimate the descent and mixing rates within the vortex.

The ER-2 will be employed to study the composition of air both upstream, within, and downstream of PSCs and cold sulfate aerosols. The DC-8 observations during midwinter will be used as initializations of microphysical and chemical models for testing against the ER-2 observed radical concentrations over a variety of scenarios in the high-latitude polar regions. The synergy of the DC-8 and ER-2 observations provides a significant addition to our ability to interpret the photochemistry of the mid- to late-winter period. Radical measurements (OH, HO_2, ClO, ClOOCl, BrO, NO, and NO_2) from the ER-2 provide a unique opportunity to directly calculate these mid- to late-winter ozone loss rates. Because of this unique capability, constant flight legs at various altitudes, solar zenith angles, and Lagrangian flow conditions will be flown to test our understanding of ozone loss rates.

In conjunction with the aircraft measurements, balloon-borne trace gas, ozone, and aerosol measurements will be used to estimate descent rates and meridional mixing rates in an attempt to quantify the ozone budget in the lower stratosphere. The balloon-borne flights will use *in situ* instruments capable of providing high-precision, high-accuracy observations of long-lived tracers of atmospheric transport such as CO_2, SF_6, N_2O, CH_4, CFC-11, CFC-113, CFC-12, ozone, H_2O, pressure, and temperature in the critical altitude region between 20 and 30 km. Remote-sensing techniques (IR and UV-Vis solar occultation, and IR emission) will be needed to measure N_2O, H_2O, CH_4, HF, CFC-11, CFC-113, CFC-12, ozone, pressure, and temperature as well as photochemically active gases NO, NO_2, N_2O_5, HNO_3, HNO_4, $ClONO_2$, HOCl, HCl, H_2O_2, and ozone. The remote measurements of photochemically active nitrogen and halogen gases will allow quantification of the efficiency of heterogeneous processing in the 22- to 26-km altitude region, while the remote measurements of HNO_3, total NO_y, N_2O, and H_2O will provide important constraints on the phase and composition of PSCs and possibly on the mechanism for denitrification.

A series of launches of these balloons to high altitudes over the course of the winter will allow us to follow the descent of air using the long-lived constituents. These multiple balloon launches will allow us to validate calculated descent (such as that shown in Figure 3).

2.1.3 Uncertainties associated with conventional techniques for calculating chemically driven ozone losses

The DC-8 can provide thousands of ozone profiles over the breadth of the polar vortex during each of its deployments. The "match" technique utilizes trajectories to determine the movement of air following its sampling by ozonesondes. The vortex transects provided by the DC-8 can yield many more profiles than are available from ozonesondes. In order to obtain comparable results, lidar ozone and temperature profiles will be combined to obtain a much more detailed picture of the polar vortex. By using forward trajectories, flight profiles can be designed to optimize the re-sampling of air obtained on earlier flights. The combination of flights can be used as an independent assessment of the "match" technique, as well as other techniques that have been used to calculate ozone loss in the Northern Hemisphere.

2.2 Processes that Extract and Insert Nitrogen and Chlorine Compounds into Reservoir Species and the Distinction between Liquid and Solid Phases

As mentioned in Section 1.2, the critical period for ozone loss occurs as the sun begins to return to the Arctic during the January to April period. While inorganic chlorine is converted into photolytically active forms by particles, the rising of the sun over the Arctic provides the energy flux necessary for fueling the catalytic reactions for ozone loss. Hence, the ER-2 flights will be optimized to sample the February to March period.

Because PSCs and cold sulfate aerosols are crucial to processing of polar vortex air, it is critical to sample air that is both upstream and downstream of polar processing events. As noted in Section 1.2, mountain forced gravity waves over northern Scandinavia can produce such processing events. Flights of the ER-2 will be attempted in these areas to assess the chemical balance both upstream and downstream of such processing events. In addition to the mountain wave events, we will attempt to sample larger synoptic scale systems with rather longer temperature time scales than mountain wave. DC-8 flights oriented along Lagrangian paths in the lower stratosphere will also be used to gain an understanding of the thermal structure of these mountain and synoptic scale waves.

2.2.1 Chlorine activation and denitrification

Proposed ER-2 flights upstream, downstream, and within PSCs and the cold sulfates will require measurements of both chlorine and nitrogen species. HCl and $ClONO_2$ are converted into Cl_2 on the surfaces of particles, and this Cl_2 is photolyzed by sunlight. *In situ* observations of HCl, $ClONO_2$, Cl_2O_2, and ClO along flight paths parallel to the wind (quasi-Lagrangian observations) will determine heterogeneous conversion. *In situ* observations of HNO_3 and H_2O measured in the same quasi-Lagrangian fashion will allow assessment of denitrification processes. *In situ* particle surface areas and temperatures provide key inputs for such quasi-Lagrangian studies. Wind observations will be used to determine the behavior of the mountain forced waves, and the degree of success in flying Lagrangian paths. Column observations of chlorine and nitrogen species measured from the DC-8 can also be utilized to assess the degree of processing both upstream and downstream of cold regions where heterogeneous processing occurs.

Meteorological analyses indicate that the warming phase of air parcel motion occurs typically to the east of Norway during the late winter. Therefore, these Lagrangian flights will need to be principally flown over such countries as Iceland, Norway, Sweden, Finland, and Russia.

2.2.2 Chlorine deactivation

ClO deactivation is critical to an accurate calculation of the net loss of ozone over the course of the winter. The principal method for deactivation is understood to be the reaction of ClO with NO_2 to form $ClONO_2$. The NO_2 comes from the photolysis of HNO_3 by sunlight. Recurring observations of the nitrogen and chlorine species by balloons and DC-8 column measurements over the course of the winter will determine the degree of Cl activation. Similarly, *in situ* ER-2 measurements and DC-8 column measurements in late winter will be used to assess Cl deactivation during that period. In addition, Lagrangian flights of the ER-2 can be utilized to assess the conversion of ClO to $ClONO_2$. *In situ* observations of HNO_3, NO_2, ClO, and $ClONO_2$ along with photolytic measurements of the ultraviolet (UV) and visible spectrum will be used to validate our current understanding of the photochemistry of air downstream of heterogeneous processing events.

2.2.3 Halogen activation on cirrus

Regions of active formation of cirrus have not been the focus of previous missions, and aircraft *in situ* ClO instruments have typically been operated primarily only in the stratosphere to protect the optical instruments from condensation in the troposphere. We hope to make *in situ* measurements of ClO, BrO, OH, and HO_2 in the lower stratosphere and upper troposphere, because ozone loss is potentially enhanced if halogens are activated by lower stratospheric aerosols and cirrus. Important adjunct measurements will be particle surface area, water vapor, temperature, and tracers (needed to estimate Cl_y and Br_y). Other useful measurements are HNO_3 and HOCl. If *in situ* measurements of nitric acid are not available then measurements of NO_y (e.g., NO, NO_2, HNO_4, N_2O_5, $ClONO_2$, and HNO_3) and NO_2 or NO can indicate the amount of HNO_3 and active nitrogen radicals. Changes in NO_y amounts should occur in the presence of cloud ice particles, thus we expect that proposed NO_y measurements will use dual inlet techniques to estimate particle HNO_3 amounts. Nadir-viewing aerosol lidar measurements and knowledge of the tropopause height from temperature profiles will also provide a survey of the occurrence of cirrus in the lower stratosphere.

2.3 Properties of Cold Aerosols and Polar Stratospheric Clouds

There are several techniques for determining the composition of the polar stratospheric clouds using *in situ* and remote observations. We will attempt to observe PSCs at infrared wavelengths using remote instruments aboard the DC-8. Spectra of nitric acid trihydrate (NAT), nitric acid dihydrate (NAD), and ternary $HNO_3/H_2SO_4/H_2O$ solutions will be measured. A disadvantage of the technique is that a long path is required. Hence, small volume PSCs may be difficult to detect, as is apparent in Figure 5. Also, since sunlight is required for the observation, only PSCs near the low-latitude edge of the vortex are observable in midwinter and the aircraft must be properly positioned to observe the sun low on the horizon. Of course, low sun angles are also required for coincident SAGE III validation measurements.

In situ observations of condensation nuclei, aerosols, and particles require observations of size spectra, volume and surface area, physical properties, and composition. ER-2 flights into regions containing PSCs and cold aerosol particles will be a priority. As with the chemical studies (see previous sections), we will attempt quasi-Lagrangian flights both upstream of the cold pools, into, and downstream of these cold pools. Further balloon-borne remote-sensing measurements and aircraft *in situ* observations of the concentration of gaseous HNO_3, H_2O, combined with laboratory vapor pressure data, provide strong constraints on the phase and composition of PSCs. Again, these quasi-Lagrangian flights will require flights over high northern countries such as Iceland, Norway, Sweden, Finland, and Russia.

2.4 SAGE III Validation

2.4.1 Aircraft measurements for SAGE III validation

2.4.1.1 Ozone

SAGE III will measure ozone concentration from cloud top to 85 km with an accuracy of about 6% at the peak and a vertical resolution of 0.5 km. Validation of this product over this height range is beyond the scope of this mission. Instead, this mission will focus on obtaining correlative ozone measurements in the upper troposphere and lower to mid-stratosphere. Accurate knowledge of ozone trends in this region near the tropopause is critical for assessing radiative forcing. Historically, this is the same altitude regime in which SAGE II has had its greatest uncertainties in ozone trend assessments [Harris *et al.*, 1997].

To address the vertical extent of the SAGE III ozone measurement variability over the slant path (line-of-sight) of approximately 200 km for a given altitude, we hope to include zenith viewing lidar measurements of stratospheric ozone concentrations on the DC-8 instrument payload. Lidar measurements provide high precision, but have lower accuracy; thus, an *in situ* ozone concentration measurement should be included on both the ER-2 and DC-8. Lidar profile measurements should extend to an altitude of at least 10 km above flight altitude. *In situ* observations should cover an altitude range from the upper troposphere to above 20 km.

2.4.1.2 Aerosols

SAGE III will measure aerosol extinction at seven wavelengths ranging from 385 to 1550 nm in the troposphere and stratosphere. Validation of these measurements as well as inferred products such as aerosol surface area will be based on intercomparisons with different instruments. We anticipate that a number of aerosol instruments identified in the SAGE III validation plan [McCormick *et al.*, 1997] will be included in SOLVE.

Lidar aerosol and cloud measurements

Vertical lidar backscatter measurements provide an excellent method for examining the vertical and horizontal variability of aerosol and optically thin cloud along the SAGE slant path. Because the aerosol lidar retrieval is strongly affected by the normalization procedure, measurements should reach heights above 30 km, where the return is dominated by Rayleigh scattering. Measurements must have 0.5 km vertical resolution or better. Depolarization measurements are further required to discriminate between spherical and non-spherical particles. In support of these measurements, observations from a zenith viewing all-sky camera may also be desired to aid in the interpretation of clouds along the SAGE slant path.

In situ particle samplers

The multi-wavelength SAGE III aerosol measurements provide estimates of aerosol surface area. Well-calibrated instruments are needed to validate these estimates over aerosol particle size distributions in the sub-micron size range. Aerosol composition in the stratosphere and upper troposphere is needed to examine variability of the backscatter-to-extinction conversion factor. Instruments should be able to measure particle optical surface area to better than a factor of two.

In addition, knowledge of the surface area of cirrus is required to understand the heterogeneous chemistry that may occur on such clouds. Replicators and holographic instruments that are capable of sizing ice crystals in the size regime below 50 **m**m would be useful. Consideration will also be given to instruments that measure ice water content.

Finally, we need to better understand the mode of formation of new particles in the upper troposphere and lower stratosphere. This requires measurements of the size distributions of particles beyond the few nanometer size range with good temporal resolution. There are currently no such data from the lower stratosphere and very few from the troposphere above the boundary layer.

2.4.1.3 Sun photometer

Solar photometers can provide slant-path optical depth measurements at many of the same wavelengths measured by SAGE III. Such measurements can further be differentiated during aircraft ascents or descents to yield vertical extinction profiles for intercomparison. With such an instrument on the aircraft, profiles can be compared to those calculated by *in situ* particle samplers or inferred from lidar backscatter observations.

2.4.1.4 Water vapor

Although water vapor measurements of the upper troposphere and lower stratosphere have been conducted since the late 1940s, considerable disagreement remains between different measurement techniques. Consequently, SAGE III validation will include a series of water vapor measurement intercomparisons to bracket its accuracy against other aircraft and balloon instruments. Water vapor measurements with an accuracy of ~10% for the upper troposphere and <25% for the stratosphere will be needed. These observations will also be used to understand SAGE III aerosol/cloud measurements.

Because of the variability of water vapor in the troposphere, lidar profile measurements are required to examine its inhomogeneity along the SAGE III slant path. Measurements are also desired in the stratosphere, where variations near PSCs could provide insight on cloud formation. Such profile measurements should extend at least 10 km above and 5 km below flight altitude in clear sky conditions.

2.4.1.5 Temperature

SAGE III will make temperature profile measurements, a capability not realized by either of its predecessors. Temperature profiles also will be used to help interpret PSC measurements and to calculate the altitude of the tropopause. Profile measurements are needed from a point several kilometers below the aircraft to a height of about 35 km. It is envisioned that several instruments will be needed to satisfy this requirement.

2.4.1.6 Altitude registration of transmission profiles

The accurate determination of the transmission profile is fundamental to the retrieval of all species. For SAGE I, altitude registration errors of about 200 to 400 m resulted in biases in ozone mixing ratio and other species [Wang *et al.*, 1996]. For SAGE III, altitude registration with an uncertainty of < 100 m is desired. Validation may be achieved by measuring the altitude of the top of an optically thick cloud that lies along the slant path. It may also be achieved by matching profiles of aerosol, ozone, and water vapor, especially near the tropopause where strong vertical gradients exist. A combination of upward and downward viewing lidar profiles acquired along aircraft survey and staircase flights should provide this information. *In situ* measurements of tracers, temperature, and pressure from the troposphere to ER-2 flight altitudes will also aid in these estimates.

2.4.1.7 Facility measurements

ER-2 and DC-8 facility measurements of time, position (latitude, longitude, and both radar and pressure altitude), attitude angles, and *in situ* temperature will be available to investigators.

2.4.2 Balloon-borne measurements for SAGE III validation

Balloon-borne remote-sensing observations provide an additional validation means for the SAGE III satellite instrument. The balloon-borne observations of ozone and H_2O, which have been compared extensively to *in situ* data and have served as correlative measures for a number of instruments onboard the UARS, will be used in a similar capacity for SAGE III validation. *In situ* observations of ozone and H_2O will also be used for such validation efforts. The remotely sensed balloon-borne observations of ozone and H_2O can serve as a bridge between the *in situ* and SAGE III observations because both SAGE III and balloon solar occultation instruments (both UV-Visible (UV-Vis) and infrared) have comparable vertical and horizontal resolution. Measurements of NO_2 will be used for validation of SAGE III measurements of this species; similar viewing geometries are particularly helpful owing to the strong dependence of concentrations of NO_2 on solar zenith angle. *In situ* measurements of aerosol surface area will provide validation for SAGE III estimates of this parameter. The balloon-borne instruments will not obtain observations of NO_3 and OClO, two gases measured by SAGE III. However, balloon measurements of vertical profiles of every important gas in the NO_y family other than NO_3 (e.g., NO, NO_2, HNO_4, N_2O_5, $ClONO_2$, and HNO_3) as well as ozone will, together with photochemical models, provide useful constraints for the interpretation of SAGE III measurements of NO_3. In a similar manner, the balloon-borne observations of vertical profiles of ClO, HCl, and ozone would be particularly useful for guiding the interpretation of SAGE III measurements of OClO.

3 MEASUREMENT REQUIREMENTS/INSTRUMENTATION

3.1 ER-2 Payload

Potential ER-2 instrumentation is listed below for this proposed mission. The basic mission consists of measurements 1 through 7 that meet SAGE III validation requirements and basic ozone loss science objectives. Instruments 9 through 14 complement these basic objectives with the additional science objectives discussed above.

1) Ozone profile (*in situ*)
2) Inorganic chlorine species (*in situ*, ClO, HCl, $ClONO_2$, ClOOCl)
3) Aerosol (size distribution, 0.1-50 **m**m, 0-0.1 **m**m, CN)
4) Temperature, Pressure, and winds (*in situ*)
5) Temperature profile (remote, microwave or lidar)
6) Water vapor (*in situ*)
7) Nitrogen species (*in situ*, NO_2, NO, HNO_3, NO_y)
   - Meets basic mission SAGE III validation and observed ozone loss requirements
8) Long-lived trace gases (*in situ*, e.g., N_2O, CFC-11, CFC-12)
9) *In situ* radicals (OH, HO_2)
10) Organic chlorine species (HCFCs, CFCs)
11) Tracers of atmospheric motion (SF_6, CO_2, CO, etc.)

11) UV-visible spectra (used for photolysis computations)
12) Overhead column ozone
    - Adds mission capability for investigating photochemistry and dynamics in the lower stratosphere

Instrument selection will be based upon a combination of cost, measurement priority, heritage of the measurements/instruments proposed, and available payload space on the ER-2. At the end of each flight, each investigator will be required to produce a preliminary data set for exchange with other investigators and the theory team. A final submission of data with supporting documentation is required to a central data facility approximately six months following completion of the mission. Investigator teams are also expected to participate in a SAGE III validation.

3.2 DC-8 Payload

Potential DC-8 instrumentation is listed below in approximate priority. The basic mission consists of measurements 1 through 9, which meet SAGE III validation requirements and ozone-loss science objectives. Instruments 10 through 14 complement these basic objectives with the additional science objectives discussed above.

1) Ozone profile (lidar)
2) Aerosol profile (lidar)
3) Aerosol optical depth (sun photometer)
4) Temperature profile (lidar, microwave)
5) Water vapor profile (troposphere)
6) *In situ* water vapor
7) *In situ* ozone
8) *In situ* aerosols - 0.1-5 **m**m, 0-0.1 **m**m (CN)
9) Water vapor profile (lidar, stratosphere)
    - Meets basic mission SAGE III validation and observed ozone loss requirements
10) *In situ* long lived trace gases (CO, N_2O, CH_4, CFCs)
11) *In situ* radicals (ClO, BrO, OH, HO_2)
12) *In situ* aerosols - >5 **m**m
13) *In situ* reservoir gases (HOCl, HNO_3)
    - Adds mission capability for investigating halogen/nitrogen chemistry in the lower stratosphere
14) Solar Fourier transform spectrometry
    - Adds mission capability for investigating PSC composition

Instrument selection will be based upon a combination of cost, measurement priority, heritage of the measurements/instruments proposed, and available space on the DC-8. At the end of each flight, each investigator will be required to produce a preliminary data set for exchange with other measurement investigators and the theory team. Because of the volume of the lidar data, a field set of CD-ROMs or high-capacity removable magnetic media may be produced for exchange using the Ames Aircraft Hipskind/Gaines format. A final submission of data with supporting documentation is required to a central data facility approximately six months following completion of the mission. Investigator teams are also expected to participate in SAGE III validation.

3.3 Balloon Payload

The desired balloon-borne measurements are listed below. We expect that the balloon payloads will be similar to those flown during the *in situ* (Observations from the Middle Stratosphere, OMS) and remote-sensing components of the Stratospheric Tracers of Atmospheric Transport (STRAT) and Photochemistry of Ozone Loss in the Arctic Region in Summer (POLARIS) aircraft missions.

Remote sensing, infrared solar occultation and/or emission: Ozone, N_2O, CH_4, NO, NO_2, HNO_3, HNO_4, HCl, HOCl, $ClONO_2$, CH_3Cl, CFC-11, CFC-12, CCl_4, CFC-113, H_2O, HF, SF_6, P, T, ...

Remote sensing, UV-Vis solar occultation: Ozone, NO_2, OClO, BrO, aerosols, ...

Remote sensing, submillimeter wave emission: ClO, ozone, HCl, ...

These observations provide simultaneous measurements of long-lived tracers, the major components of the nitrogen and chlorine families, and ozone and water vapor. Ideally, if different types of instruments are deployed, they should be flown together on the same gondola, using both ozone and/or HCl to indicate how well the two are looking at the same airmass.

In situ: Ozone, CO_2, N_2O, CH_4, HCl, CFC-11, CFC-12, CFC-113, SF_6, P, T, aerosol characteristics, and H_2O.

These observations provide the simultaneous measurements of long-lived tracers for determining the age of the air and give the useful scatter plots for measurements that are the same as those made in the middle latitudes, the summertime high latitudes, and the tropics.

If the existing OMS *in situ* gondola is used, then water vapor, aerosols, and/or ozone may be measured (additionally or separately) on free-flying balloons launched simultaneously. This approach has been the most successful for getting high-quality water vapor measurements simultaneous with the other long-lived tracer measurements during previous OMS flights.

3.4 Theoretical Investigations

Theoretical, analytical, modeling, and observational analyses during and after deployments have provided tremendous enhancements to the interpretation of data collected in previous field missions. Theory teams will be actively encouraged to participate in SOLVE. This theory involvement will be built around a number of areas. In particular, modeling efforts such as two- and three-dimensional global modeling efforts, microphysical models, photochemical steady-state models, chemistry-on-trajectory models, mesoscale models, and gravity wave models are encouraged. Further, theoretical analyses which combine a variety of data sets are strongly encouraged.

Meteorological forecasts of ground conditions and stratospheric fields will be primary needs for directing ER-2, DC-8, and balloon operations. In addition, other innovative theoretical teams are encouraged to participate in SOLVE.

Theory investigations are expected to actively participate in mission development activities, in-field operations, and post-mission analysis of the data. Pre-mission activities will include: 1) refinement and prioritization of science questions, 2) development of measurement and basing priorities, 3) development of proposed flight paths, and 4) establishment of working relationships with instrument teams. The theory teams are expected to spend time in the field during the mission to: 1) provide direct support for mission planning; 2) obtain first-hand familiarity with the airborne, satellite, and balloon data; and 3) to collaborate with the measurement investigators in interpretation of the data. Other mission-related activities will involve attendance at all science team meetings, the development of the mission summary, the preparation of peer-reviewed journal publications, and the participation in aircraft assessments to represent the findings from the various SOLVE measurements.

4. MISSION LOGISTICS

An initial science team meeting for selected investigators and program/project management will be held in late 1998 at a location yet to be determined. The overall tentative mission schedule has the following deployments.

- 7-21 October 1999 - balloon, *in situ*
- 1-15 December - balloon, remote sensing
- 1-15 December - DC-8
- 15 January 2000 - balloon, remote sensing
- 15-29 January - DC-8
- 21 January - balloon *in situ*
- 1 February -14 March – ER-2
- 1-15 March - DC-8

4.1 ER-2 Deployment Schedule

The tentative schedule for the ER-2 is as follows:

- Instrument certification will be staggered over the course of 1999.

- Full payload integration begins early January 2000.

- Test flights will be conducted from mid- to late January 2000.

- A 4- to 6-week ER-2 deployment will be centered around 21 February 2000 (1 February through 14 March).

Mission locations for the ER-2 are under consideration and will be finalized in 1998. Under consideration are the previously utilized installations such as Stavanger, Norway. Laboratory space will be set up commensurate with an instrument teams needs. Theory teams are expected to bring their own data analysis computers into the field. Internet connections will be available with some limited bandwidth. Experienced meteorological support teams for ground and air operations forecasting will also be considered.

4.2 DC-8 Deployment Schedule

The tentative schedule for the DC-8 is as follows:

- The DC-8 integration and test flights will occur in November 1999.
- The DC-8 flights will be staged in three segments: 1-15 December 1999, 15-29 January 2000, and 1-15 March 2000.

Mission locations for the DC-8 are under consideration and will be finalized in 1998. Under consideration are the U.S. or NATO military installations at Stavanger, Norway; Keflavik, Iceland; or Fairbanks, Alaska. Experimenters can expect heated hanger space, but limited telecommunications and ground lab facilities. Theory teams are expected to bring their own data analysis computers into the field. Internet connections are not guaranteed except through commercial analog telephone service. Proposals from an experienced meteorological support team will also be considered.

4.3 Balloon Launch Schedule

Balloon operations will be conducted by the National Scientific Balloon Facility. They will provide the balloon-launching capability, telemetry, and recovery as they have for operations in New Mexico, Texas, Brazil, and Alaska. Free-flying, hand-launched balloons may be necessary for water vapor, aerosols, and/or ozone, in which case, the investigators would be responsible for the launches.

Four sites have been proposed for balloon flights: Sondestrom, Greenland (67.0˚N, 50.7˚W), Thule, Greenland (76.5˚N, 68.7˚W), Kiruna, Sweden (67.8˚N, 20.4˚E), or Andoya, Norway (69.3˚N, 16.0˚E). The goal is to have the launches of the various *in situ* and remote-sensing balloon payloads as close together in time and space as possible. However, it may be necessary to have separate locations for the remote-sensing and *in situ* payloads in order to achieve the goals of making measurements of long-lived species within the forming Arctic vortex for the *in situ* payload and overlapping measurements by the balloon-borne remote sensing and SAGE III instruments. Experimenters can expect limited telecommunications and ground lab facilities at these locations. Internet connections are not guaranteed except through commercial analog telephone service. The selection of a site will depend on the surface winds, logistical issues, and costs.

<u>Launch periods</u>

7-21 October 1999 - *In situ* instruments

The goal is to launch the balloon payloads into the Arctic polar vortex as the vortex is in its initial stage of development (October), and later (December and January) as the vortex nears its full development stage prior to the coldest part of the year. A second goal is to make observations close in time and space to a SAGE III overpass. Both remote-sensing and *in situ* payloads will be deployed. Deployment of the remote-sensing payload can be from all possible sites except Thule, which is too far into polar night. The selection of a site will need to be based in part on the wind climatology, which will dictate the overall chances of achieving a launch.

1-15 December 1999 - Remote sensing instruments; overlap with first DC-8 deployment

The temperatures will be dropping at the higher altitudes, giving an opportunity to use *in situ* and/or remote-sensing instruments to measure the changes in nitrogen and chlorine partitioning caused by cold heterogeneous processes as a function of altitude (and thus pressure, temperature, and aerosol loading). Furthermore, near simultaneous launches will allow an intercomparison of the *in situ* and remote-sensing payloads.

15 January 2000 - Remote sensing instruments
21 January 2000 - *In situ* instruments; overlap with second DC-8 deployment

This launch series, together with the October and December launches, should also provide information about the descent rates and meridional transport associated with the Arctic polar vortex in the November to January time frame. The vortex is typically at its strongest and coldest during the January time period. These balloon launches will allow a clear understanding of the vortex evolution and provide constituent information just prior to the deployment of the ER-2.

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6 FIGURES

Figure 1. Polar orthographic images of March averaged total ozone. The years 1971 and 1972 are derived from the Nimbus-4 BUV instrument; 1979, 1990, and 1993 are from the Nimbus-7 TOMS instrument; 1996 is from the NOAA-14 SBUV-2 instrument; and the 1997 data is from the EP-TOMS instrument.

Figure 2. Sticking coefficients (gamma) versus temperature from a sample of evaluations of laboratory measurements on liquid sulfate, SAT, and NAT. The sticking coefficients on liquid sulfate are taken from Hanson and Ravishankara [1994], Hanson *et al.* [1994], WMO [1991], and DeMore *et al.* [1994] (JPL-94). The sticking coefficients on SAT from Zhang *et al.* [1994] are recommended in DeMore *et al.* [1994]. Sticking coefficients for HCl + $ClONO_2$ on SAT and NAT from Hanson and Ravishankara [1993] are also shown. The sticking coefficients for $ClONO_2$ + H_2O on NAT is intermediate between Hanson and Ravishankara [1993], Moore *et al.* [1990], and Abbatt and Molina [1992] with no relative humidity dependence.

Figure 3. Potential vorticity (PV) images for 1 October 1994 and 1 March 1995 on the 500-K isentropic surface. The blue line in the top images shows the approximate position of the vortex edge. The regular grid of small dots superimposed on the high PV values in the top right image (1 March) represent the initial positions of back trajectory parcels initialized inside the polar vortex. The dark points on the 1 October image are the final positions (starting points) of this air that was found inside the vortex on 1 March. The bottom plot shows the pressure altitudes of these parcels on 1 October (white dots) and 1 March (blue dots). The air has descended about 150 K (4 to 5 km) over this 150 day period.

Figure 4. Surface area coverage of cold temperatures at 50 hPa (20 km) over the course of the northern winter (y-axis) for each winter 1978/79 to 1996/97 (x-axis). The width of the lines (see scale at top left) represents the surface area coverage for three temperature thresholds: 200 K (black), 195 K (red), and 190 K (blue).

Figure 5. Airborne lidar observations of polar stratospheric clouds over northern Scandinavia [Private communication, J. Bacmeister; see also Carslaw *et al.*, 1998b].

Figure 6. Sample time-latitude coverage of METEOR/SAGE III measurements. Local satellite sunset (sunrise) occultation events are indicated by solid (dashed) lines. Moonset (moonrise) occultation events are indicated by solid (open) circles.

APPENDIX B:

INSTRUCTIONS FOR RESPONDING TO NASA RESEARCH ANNOUNCEMENTS

(JANUARY 1997)

(a) General.

(1) Proposals received in response to a NASA Research Announcement (NRA) will be used only for evaluation purposes. NASA does not allow a proposal, the contents of which are not available without restriction from another source, or any unique ideas submitted in response to an NRA to be used as the basis of a solicitation or in negotiation with other organizations, nor is a pre-award synopsis published for individual proposals.

(2) A solicited proposal that results in a NASA award becomes part of the record of that transaction and may be available to the public on specific request; however, information or material that NASA and the awardee mutually agree to be of a privileged nature will be held in confidence to the extent permitted by law, including the Freedom of Information Act.

(3) NRAs contain programmatic information and certain requirements which apply only to proposals prepared in response to that particular announcement. These instructions contain the general proposal preparation information which applies to responses to all NRAs.

(4) A contract, grant, cooperative agreement, or other agreement may be used to accomplish an effort funded in response to an NRA. NASA will determine the appropriate instrument. Contracts resulting from NRAs are subject to the Federal Acquisition Regulation and the NASA FAR. Supplement. Any resultant grants or cooperative agreements will be awarded and administered in accordance with the NASA Grant and Cooperative Agreement Handbook (NPG 5800.1).

(5) NASA does not have mandatory forms or formats for responses to NRAs; however, it is requested that proposals conform to the guidelines in these instructions. NASA may acceptp proposals without discussion; hence, proposals should initially be as complete as possible and be submitted on the proposers' most favorable terms.

(6) To be considered for award, a submission must, at a minimum, present a specific project within the areas delineated by the NRA; contain sufficient technical and cost information to permit a meaningful evaluation; be signed by an official authorized to legally bind the submitting organization; not merely offer to perform standard services or to just provide computer facilities or services; and not significantly duplicate a more specific current or pending NASA solicitation.

(b) NRA-Specific Items. Several proposal submission items appear in the NRA itself: the unique NRA identifier; when to submit proposals; where to send proposals; number of copies required; and sources for more information. Items included in these instructions may be supplemented by the NRA.

(c) The following information is needed to permit consideration in an objective manner. NRAs will generally specify topics for which additional information or greater detail is desirable. Each proposal copy shall contain all submitted material, including a copy of the transmittal letter if it contains substantive information.

(1) Transmittal Letter or Prefatory Material.

(i) The legal name and address of the organization and specific division or campus identification if part of a larger organization;

(ii) A brief, scientifically valid project title intelligible to a scientifically literate reader and suitable for use in the public press;

(iii) Type of organization: e.g., profit, nonprofit, educational, small business, minority, women-owned, etc.;

(iv) Name and telephone number of the principal investigator and business personnel who may be contacted during evaluation or negotiation;

(v) Identification of other organizations that are currently evaluating a proposal for the same efforts;

(vi) Identification of the NRA, by number and title, to which the proposal is responding;

(vii) Dollar amount requested, desired starting date, and duration of project;

(viii) Date of submission; and

(ix) Signature of a responsible official or authorized representative of the organization, or any other person authorized to legally bind the organization (unless the signature appears on the proposal itself).

(2) **Restriction on Use and Disclosure of Proposal Information**. Information contained in proposals is used for evaluation purposes only. Offerors or quoters should, in order to maximize protection of trade secrets or other information that is confidential or privileged, place the following notice on the title page of the proposal and specify the information subject to the notice by inserting an appropriate identification in the notice. In any event, information contained in proposals will be protected to the extent permitted by law, but NASA assumes

no liability for use and disclosure of information not made subject to the notice.

Notice

Restriction on Use and Disclosure of Proposal Information

The information (data) contained in [insert page numbers or other identification] of this proposal constitutes a trade secret and/or information that is commercial or financial and confidential or privileged. It is furnished to the Government in confidence with the understanding that it will not, without permission of the offeror, be used or disclosed other than for evaluation purposes; provided, however, that in the event a contract (or other agreement) is awarded on the basis of this proposal the Government shall have the right to use and disclose this information (data) to the extent provided in the contract (or other agreement). This restriction does not limit the Government's right to use or disclose this information (data) if obtained from another source without restriction.

(3) **Abstract.** Include a concise (200-300 word if not otherwise specified in the NRA) abstract describing the objective and the method of approach.

(4) **Project Description**.

(i) The main body of the proposal shall be a detailed statement of the work to be undertaken and should include objectives and expected significance; relation to the present state of knowledge; and relation to previous work done on the project and to related work in progress elsewhere. The statement should outline the plan of work, including the broad design of experiments to be undertaken and a description of experimental methods and procedures. The project description should address the evaluation factors in these instructions and any specific factors in the NRA. Any substantial collaboration with individuals not referred to in the budget or use of consultants should be described. Subcontracting significant portions of a research project is discouraged.

(ii) When it is expected that the effort will require more than one year, the proposal should cover the complete project to the extent that it can be reasonably anticipated. Principal emphasis should be on the first year of work, and the description should distinguish clearly between the first year's work and work planned for subsequent years.

(5) **Management Approach**. For large or complex efforts involving interactions among numerous individuals or other organizations, plans for distribution of responsibilities and arrangements for ensuring a coordinated effort should be described.

(6) **Personnel**. The principal investigator is responsible for supervision of the work and participates in the conduct of the research regardless of whether or not compensated under the award. A short biographical sketch of the principal investigator, a list of principal publications

and any exceptional qualifications should be included. Omit social security number and other personal items which do not merit consideration in evaluation of the proposal. Give similar biographical information on other senior professional personnel who will be directly associated with the project. Give the names and titles of any other scientists and technical personnel associated substantially with the project in an advisory capacity. Universities should list the approximate number of students or other assistants, together with information as to their level of academic attainment. Any special industry-university cooperative arrangements should be described.

(7) **Facilities and Equipment.**

(i) Describe available facilities and major items of equipment especially adapted or suited to the proposed project, and any additional major equipment that will be required. Identify any Government-owned facilities, industrial plant equipment, or special tooling that are proposed for use. Include evidence of its availability and the cognizant Government points of contact.

(ii) Before requesting a major item of capital equipment, the proposer should determine if sharing or loan of equipment already within the organization is a feasible alternative. Where such arrangements cannot be made, the proposal should so state. The need for items that typically can be used for research and non-research purposes should be explained.

(8) **Proposed Costs.**

(i) Proposals should contain cost and technical parts in one volume: do not use separate "confidential" salary pages. As applicable, include separate cost estimates for salaries and wages; fringe benefits; equipment; expendable materials and supplies; services; domestic and foreign travel; ADP expenses; publication or page charges; consultants; subcontracts; other miscellaneous identifiable direct costs; and indirect costs. List salaries and wages in appropriate organizational categories (e.g., principal investigator, other scientific and engineering professionals, graduate students, research assistants, and technicians and other non-professional personnel). Estimate all staffing data in terms of staff-months or fractions of full-time.

(ii) Explanatory notes should accompany the cost proposal to provide identification and estimated cost of major capital equipment items to be acquired; purpose and estimated number and lengths of trips planned; basis for indirect cost computation (including date of most recent negotiation and cognizant agency); and clarification of other items in the cost proposal that are not self-evident. List estimated expenses as yearly requirements by major work phases.

(iii) Allowable costs are governed by FAR Part 31 and the NASA FAR Supplement Part 1831 (and OMB Circulars A-21 for educational institutions and A-122 for nonprofit organizations).

(9) **Security**. Proposals should not contain security classified material. If the research requires access to or may generate security classified information, the submitter will be required to comply with Government security regulations.

(10) **Current Support**. For other current projects being conducted by the principal investigator, provide title of project, sponsoring agency, and ending date.

(11) **Special Matters.**

(i) Include any required statements of environmental impact of the research, human subject or animal care provisions, conflict of interest, or on such other topics as may be required by the nature of the effort and current statutes, executive orders, or other current Government-wide guidelines.

(ii) Proposers should include a brief description of the organization, its facilities, and previous work experience in the field of the proposal. Identify the cognizant Government audit agency, inspection agency, and administrative contracting officer, when applicable.

(d) **Renewal Proposals**

(1) Renewal proposals for existing awards will be considered in the same manner as proposals

for new endeavors. A renewal proposal should not repeat all of the information that was in the original proposal. The renewal proposal should refer to its predecessor, update the parts that are no longer current, and indicate what elements of the research are expected to be covered during the period for which support is desired. A description of any significant findings since the most recent progress report should be included. The renewal proposal should treat, in reasonable detail, the plans for the next period, contain a cost estimate, and otherwise adhere to these instructions.

(2) NASA may renew an effort either through amendment of an existing contract or by a new award.

(e) **Length.** Unless otherwise specified in the NRA, effort should be made to keep proposals as brief as possible, concentrating on substantive material. Few proposals need exceed 15-20 pages. Necessary detailed information, such as reprints, should be included as attachments. A complete set of attachments is necessary for each copy of the proposal. As proposals are not returned, avoid use of "one-of-a-kind" attachments.

(f) **Joint Proposals**.

(1) Where multiple organizations are involved, the proposal may be submitted by only one of them. It should clearly describe the role to be played by the other organizations and indicate the legal and managerial arrangements contemplated. In other instances, simultaneous submission of related proposals from each organization might be appropriate, in which case parallel awards would be made.

(2) Where a project of a cooperative nature with NASA is contemplated, describe the contributions expected from any participating NASA investigator and agency facilities or equipment which may be required. The proposal must be confined only to that which the proposing organization can commit itself. "Joint" proposals which specify the internal arrangements NASA will actually make are not acceptable as a means of establishing an agency commitment.

(g) **Late Proposals**. A proposal or modification received after the date or dates specified in an NRA may be considered if doing so is in the best interests of the Government.

(h) **Withdrawal.** Proposals may be withdrawn by the proposer at any time before award. Offerors are requested to notify NASA if the proposal is funded by another organization or of other changed circumstances which dictate termination of evaluation.

(i) **Evaluation Factors**

(1) Unless otherwise specified in the NRA, the principal elements (of approximately equal weight) considered in evaluating a proposal are its relevance to NASA's objectives, intrinsic

merit, and cost.

(2) Evaluation of a proposal's relevance to NASA's objectives includes the consideration of the potential contribution of the effort to NASA's mission.

(3) Evaluation of its intrinsic merit includes the consideration of the following factors of equal importance:

(i) Overall scientific or technical merit of the proposal or unique and innovative methods, approaches, or concepts demonstrated by the proposal.

(ii) Offeror's capabilities, related experience, facilities, techniques, or unique combinations of these which are integral factors for achieving the proposal objectives.

(iii) The qualifications, capabilities, and experience of the proposed principal investigator, team leader, or key personnel critical in achieving the proposal objectives.

(iv) Overall standing among similar proposals and/or evaluation against the state-of-the-art.

(4) Evaluation of the cost of a proposed effort may include the realism and reasonableness of the proposed cost and available funds.

(j) **Evaluation Techniques**. Selection decisions will be made following peer and/or scientific review of the proposals. Several evaluation techniques are regularly used within NASA. In all cases proposals are subject to scientific review by discipline specialists in the area of the proposal. Some proposals are reviewed entirely in-house, others are evaluated by a combination of in-house and selected external reviewers, while yet others are subject to the full external peer review technique (with due regard for conflict-of-interest and protection of proposal information), such as by mail or through assembled panels. The final decisions are made by a NASA selecting official. A proposal which is scientifically and programmatically meritorious, but not selected for award during its initial review, may be included in subsequent reviews unless the proposer requests otherwise.

(k) **Selection for Award**.

(1) When a proposal is not selected for award, the proposer will be notified. NASA will explain generally why the proposal was not selected. Proposers desiring additional information may contact the selecting official who will arrange a debriefing.

(2) When a proposal is selected for award, negotiation and award will be handled by the procurement office in the funding installation. The proposal is used as the basis for negotiation. The contracting officer may request certain business data and may forward a model award instrument and other information pertinent to negotiation.

(l) **Cancellation of NRA**. NASA reserves the right to make no awards under this NRA and to cancel this NRA. NASA assumes no liability for canceling the NRA or for anyone's failure to receive actual notice of cancellation.

APPENDIX C:

Proposal Cover Sheet

NASA Research Announcement 98-OES-08
Proposal No. ____________________ (Leave Blank for NASA Use)

Title: ____

Principal Investigator::____

Department:____

Institution: ____

Street/PO Box: ____

City: ____________________ State: ___________ Zip: ___________________

Country: _________________ E-mail: _______________________________________

Telephone: _______________________ Fax: __________________________________

Co-Investigators:

Name	Institution	Telephone
__________________	_____________________________	________________________
__________________	_____________________________	________________________
__________________	_____________________________	________________________

Budget:
1st Year: _________ 2nd Year: __________ 3rd Year: _________ Total: ____________

Certification of Compliance with Applicable Executive Orders and U.S. Code

By submitting the proposal identified in this *Cover Sheet/Proposal Summary* in response to this Research Announcement, the Authorizing Official of the proposing institution (or the individual proposer if there is no proposing institution) as identified below:

- certifies that the statements made in this proposal are true and complete to the best of his/her knowledge;
- agrees to accept the obligations to comply with NASA award terms and conditions if an award is made as a result of this proposal; and
- confirms compliance with all provisions, rules, and stipulations set forth in the two Certifications contained in this NRA [namely, (i*) Certification of Compliance with the NASA Regulations Pursuant to Nondiscrimination in Federally Assisted Programs*, *and (ii) Certifications, Disclosures, And Assurances Regarding Lobbying, Debarment & Suspension, And Drug-Free Workplace Requirements*].

Willful provision of false information in this proposal and/or its supporting documents, or in reports required under an ensuing award, is a criminal offense (U.S. Code, Title 18, Section 1001).

Title of Authorizing Institutional Official: ______________________________

Signature: ______________________ Date: ______________

Name of Proposing Institution: ______________________________

Telephone: ___________ E-mail:______________ Facsimile: __________

Certification of Compliance with the NASA Regulations Pursuant to Nondiscrimination in Federally Assisted Programs

The *(Institution, corporation, firm, or other organization on whose behalf this assurance is signed, hereinafter called "Applicant ")* hereby agrees that it will comply with Title VI of the Civil Rights Act of 1964 (P.L. 88-352), Title IX of the Education Amendments of 1962 (20 U.S.C. 1680 et seq.), Section 504 of the Rehabilitation Act of 1973, as amended (29 U.S.C. 794), and the Age Discrimination Act of 1975 (42 U.S.C. 16101 et seq.), and all requirements imposed by or pursuant to the Regulation of the National Aeronautics and Space Administration (14 CFR Part 1250) (hereinafter called "NASA") issued pursuant to these laws, to the end that in accordance with these laws and regulations, no person in the United States shall, on the basis of race, color, national origin, sex, handicapped condition, or age be excluded from participation in, be denied the benefits of, or be otherwise subjected to discrimination under any program or activity for which the Applicant receives federal financial assistance from NASA; and hereby give assurance that it will immediately take any measure necessary to effectuate this agreement.

If any real property or structure thereon is provided or improved with the aid of federal financial assistance extended to the Applicant by NASA, this assurance shall obligate the Applicant, or in the case of any transfer of such property, any transferee, for the period during which the real property or structure is used for a purpose for which the federal financial assistance is extended or for another purpose involving the provision of similar services or benefits. If any personal property is so provided, this assurance shall obligate the Applicant for the period during which the federal financial assistance is extended to it by NASA.

this assurance is given in consideration of and for the purpose of obtaining any and all federal grants, loans, contracts, property, discounts, or other federal financial assistance extended after the date hereof to the Applicant by NASA, including installment payments after such date on account of applications for federal financial assistance which were approved before such date. The Applicant recognized and agrees that such federal financial assistance will be extended in reliance on the representations and agreements made in this assurance, and that the United States shall have the right to seek judicial enforcement of this assurance. This assurance is binding on the Applicant, its successors, transferees, and assignees, and the person or persons whose signatures appear below are authorized to sign on behalf of the Applicant.

NASA FORM 1206

CERTIFICATIONS, DISCLOSURES, AND ASSURANCES REGARDING LOBBYING AND DEBARMENT & SUSPENSION

1. LOBBYING

As required by Section 1352, Title 31 of the U.S. Code, and implemented at 14 CFR Part 1271, as defined at 14 CFR Subparts 1271.110 and 1260.117, with each submission that initiates agency consideration of such applicant for award of a Federal contract, grant, or cooperative agreement exceeding $ 100,000, the applicant must **certify** that:

(1) No Federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned to any person for influencing or attempting to influence an officer or employee of an agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any Federal contract, the making of any Federal grant, the making of any Federal loan, the continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

(2) If any funds other than appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit a Standard Form-LLL, "Disclosure Form to Report Lobbying," in accordance with its instructions.

(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers (including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements) and that all subrecipients shall certify and disclose accordingly.

2. GOVERNMENTWIDE DEBARMENT AND SUSPENSION

As required by Executive Order 12549, and implemented at 14 CFR 1260.510, for prospective participants in primary covered transactions, as defined at 14 CFR Subparts 1265.510 and 1260.117—

(1) The prospective primary participant **certifies** to the best of its knowledge and belief, that it and its principals:

(a) Are not presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded by any Federal department or agency.

(b) Have not within a three-year period preceding this proposal been convicted of or had a civil judgment rendered against them for commission of fraud or a criminal offense in connection with obtaining, attempting to obtain, or performing a public (Federal, State or local) transaction or contract under a public transaction; violation of Federal or State antitrust statutes or commission of embezzlement, theft, forgery, bribery, falsification or destruction of records, making false statements, or receiving stolen property;

(c) Are not presently indicted for or otherwise criminally or civilly charged by a governmental entity (Federal, State or local) with commission of any of the offenses enumerated in paragraph (l)(b) of this certification; and

(d) Have not within a three-year period preceding this application/proposal had one or more public transactions (Federal, State or local) terminated for cause or default.

(2) Where the prospective primary participant is unable to certify to any of the statements in this certification, such prospective participant shall attach an explanation to this proposal.

NASA Office of Equal Opportunity Programs (OEOP)
Minority University Research and Education Division (MURED), February, 1998

APPENDIX D:

BUDGET SUMMARY

For period from ____________________ to ____________________

- Provide a complete Budget Summary for year one and separate estimated for each subsequent year.
- Enter the proposed estimated costs in Column A (Columns B & C for NASA use only).
- Provide as attachments detailed computations of all estimates in each cost category with narratives as required to fully explain each proposed cost. See *Instructions For Budget Summary* on following page for details.

		NASA USE ONLY	
	A	**B**	**C**
1. Direct Labor (salaries, wages, and fringe benefits)	________	________	________
2. Other Direct Costs:			
a. Subcontracts	________	________	________
b. Consultants	________	________	________
c. Equipment	________	________	________
d. Supplies	________	________	________
e. Travel	________	________	________
f. Other	________	________	________
3. Facilities and Administrative Costs	________	________	________
4. Other Applicable Costs:	________	________	________
5. SUBTOTAL--Estimated Costs	________	________	________
6. Less Proposed Cost Sharing (if any)	________	________	________
7. Carryover Funds (if any)			
a. Anticipated amount : ________			
b. Amount used to reduce budget	________	________	________
8. Total Estimated Costs	________	________	XXXXXXX
9. APPROVED BUDGET	XXXXXX	XXXXXXX	________

INSTRUCTIONS FOR BUDGET SUMMARY

1. Direct Labor (salaries, wages, and fringe benefits): Attachments should list the number and titles of personnel, amounts of time to be devoted to the grant, and rates of pay.

2. Other Direct Costs:
   a. Subcontracts: Attachments should describe the work to be subcontracted, estimated amount, recipient (if known), and the reason for subcontracting.
   b. Consultants: Identify consultants to be used, why they are necessary, the time they will spend on the project, and rates of pay (not to exceed the equivalent of the daily rate for Level IV of the Executive Schedule, exclusive of expenses and indirect costs).
   c. Equipment: List separately. Explain the need for items costing more than $5,000. Describe basis for estimated cost. General purpose equipment is not allowable as a direct cost unless specifically approved by the NASA Grant Officer. Any equipment purchase requested to be made as a direct charge under this award must include the equipment description, how it will be used in the conduct of the basic research proposed and why it cannot be purchased with indirect funds.
   d. Supplies: Provide general categories of needed supplies, the method of acquisition, and the estimated cost.
   e. Travel: Describe the purpose of the proposed travel in relation to the grant and provide the basis of estimate, including information on destination and number of travelers where known.
   f. Other: Enter the total of direct costs not covered by 2a through 2e. Attach an itemized list explaining the need for each item and the basis for the estimate.

3. Facilities and Administrative (F&A) Costs: Identify F&A cost rate(s) and base(s) as approved by the cognizant Federal agency, including the effective period of the rate. Provide the name, address, and telephone number of the Federal agency official having cognizance. If unapproved rates are used, explain why, and include the computational basis for the indirect expense pool and corresponding allocation base for each rate.

4. Other Applicable Costs: Enter total explaining the need for each item.

5. Subtotal-Estimated Costs: Enter the sum of items 1 through 4.

6. Less Proposed Cost Sharing (if any): Enter any amount proposed. If cost sharing is based on specific cost items, identify each item and amount in an attachment.

7. Carryover Funds (if any): Enter the dollar amount of any funds expected to be available for carryover from the prior budget period Identify how the funds will be used if they are not used to reduce the budget. NASA officials will decide whether to use all or part of the anticipated carryover to reduce the budget (not applicable to 2nd-year and subsequent-year budgets submitted for award of a multiple year award).

8. Total Estimated Costs: Enter the total after subtracting items 6 and 7b from item 5.

APPENDIX E:

GUIDELINES FOR FOREIGN PARTICIPATION

NASA accepts proposals from entities located outside the U.S. in response to this NRA. Proposals from non-U.S. entities should not include a cost plan as they are made on a no-exchange-of-funds basis. Non-U.S. proposals, and U.S. Proposals that include non-U.S. participation, must be endorsed by the respective government agency or funding/sponsoring institution in the country from which the non-U.S. participant is proposing. Such endorsement should address the following points: (1) The proposal merits careful consideration by NASA; and (2) If the proposal is selected, sufficient funds will be made available by the sponsoring foreign agency to undertake the activity as proposed.

Proposals, along with the requested number of copies and Letter of Endorsement must be forwarded to NASA in time to arrive before the deadline established for this NRA. In addition, one copy of each of these documents should be sent to:

NASA Headquarters
Office of External Relations
Earth Science Division, Code IY
Washington, DC 20546
USA

Any materials sent by courier or express mail should include the street address 300 E Street, S. W., and substitute 20024 for the indicated ZIP code.

All proposals must be typewritten in English. All non-U.S. proposals will undergo the same evaluation and selection process as those originating in the U.S. Non-U.S. proposals and U. S. Proposals that include non-U.S. participation, must follow all other guidelines and requirements described in this NRA. Sponsoring non-U.S. agencies may, in exceptional situations, forward a proposal without endorsement to the above address, if review and endorsement are not possible before the announced closing date. In such cases, however, NASA's Earth Science Division of the Office of External Relations should be advised when a decision on the endorsement is to be expected.

Successful and unsuccessful proposers will be contacted directly by the NASA Program Office coordinating the NRA. Copies of these letters will be sent to the sponsoring government agency.